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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Laboratory Determination of Lubricating Ability

The Effect of Lubrication on the Use of Exhaust Steam for Process Heating

PUBLISHED BY

THE TEXAS COMPANY

TEXACO PETROLEUM PRODUCTS

DETERMINING LUBRICATING ABILITY BY LABORATORY TESTS

IN the attainment of effective bearing lubrication there are certain controlling factors which should be given the utmost consideration. They involve both constructional characteristics and operating conditions. They alone dictate the extent to which perfect lubrication can be approached. They include:

The load
The operating speed
The bearing clearance
The viscosity of the lubricant, and
The point of application.

Theory of lubrication has proved that in practice a definite relationship exists between these factors. Theory, however, must be supplemented by laboratory study, simulating operating conditions, in order to determine as nearly as possible the suitability of any lubricant for the above conditions.

The purpose of the following article is to discuss certain of the more outstanding methods for laboratory determination of lubricating ability. Every effort is being directed today toward a more complete development of adequate testing devices. We realize that the following article is but a brief resume; we commend it, however, as a basis in studying future developments in this field.

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Laboratory Determination of Lubricating Ability

THE necessity for accurate knowledge of the lubricating ability of an oil or grease, in the interests of continuous and dependable operation of machinery has become one of the outstanding problems which confronts the lubrication specialist today. The obvious reason is that seemingly ever-increasing demand for power, speed and production which has brought about such a veritable transition in bearing design and load carrying capacity. Today bearings must be right, for they comprise the very vitals of the average machine. To this end the development of the anti-friction bearing, improvements in plain bearing design and even the utilization of wood or composition bearings have all been subjected to much concentrated study.

It is of further interest to note that means of lubrication and lubricant characteristics have been included in virtually all such bearing studies, in the realization that regardless of how theoretically perfect a bearing may be, it will most assuredly fail if effective lubrication is not maintained.

All this has called for extensive practical study of the performance of lubricants in actual operation; without a doubt a most excellent procedure, provided operating conditions are taken into consideration. It must be realized, however, that in view of the fact that operating data in connection with lubrication is chiefly of comparative value, the utmost control of operating conditions must be maintained. Unfortunately these cannot always be kept in hand; appreciable variation in temperature, speed or load, either individually or collectively, may so alter the results obtained from any specific type of lubricant as to render them of but little value as compared with the data of other tests, even though the same machinery is involved.

This used to be the practice in the United States Navy, actual operating test data being the basis on which lubricating oils were selected, even though it was impossible to check up accurately on such operations, due to the part played by the human element and the impracticability of duplicating operating conditions accurately. The result was that even though an actual operating test might prove the lubricating ability of a certain oil, the consumer, especially when buying on a price basis, was more or less dependent upon the integrity of the oil refiner.

In appreciation of these facts, lubrication technicians have devoted much time to the development of laboratory testing devices which will not only enable study of the performance of lubricants under accurately controlled conditions, which simulate operating requirements as far as possible, but which will also eliminate the time element which is always so prominent a factor in the carrying out of any actual operating test. The purpose of any such method of laboratory determination of lubricating ability is to ascertain in a short time what can be expected of a lubricant over a long period of service.

GIST OF THE MORE PROMINENT METHODS

The United States Naval Engineering Experiment Station, the Bureau of Standards, as well as many of the oil companies and certain of the machinery manufacturers have studied this matter of determining lubricating ability by means of laboratory work. The former gives weighted values to certain physical characteristics and the changes in same, after subjecting an oil to intensive accelerated service in a laboratory testing machine.

The Federal Specification Board representing the various branches of the U. S. Government has recently worked out a system for determining quality in lubricating oils based on the value of such physical characteristics as the flash point, pour point, color, carbon residue, the Sligh oxidation test, the neutralization test and the slope of the viscosity curve. The weight attached to the viscosity is based on the change in viscosity with temperature or, in other words, the flatness of the viscosity curve.

An oil to be accepted by the government must pass at least four out of seven of certain quality specifications, in addition to passing the base specification. This method is incomplete, however, in that with the exception of the Sligh oxidation test it does not take into consideration the tendency of a lubricating oil to undergo more or less change in certain of its physical and chemical characteristics in actual operation.

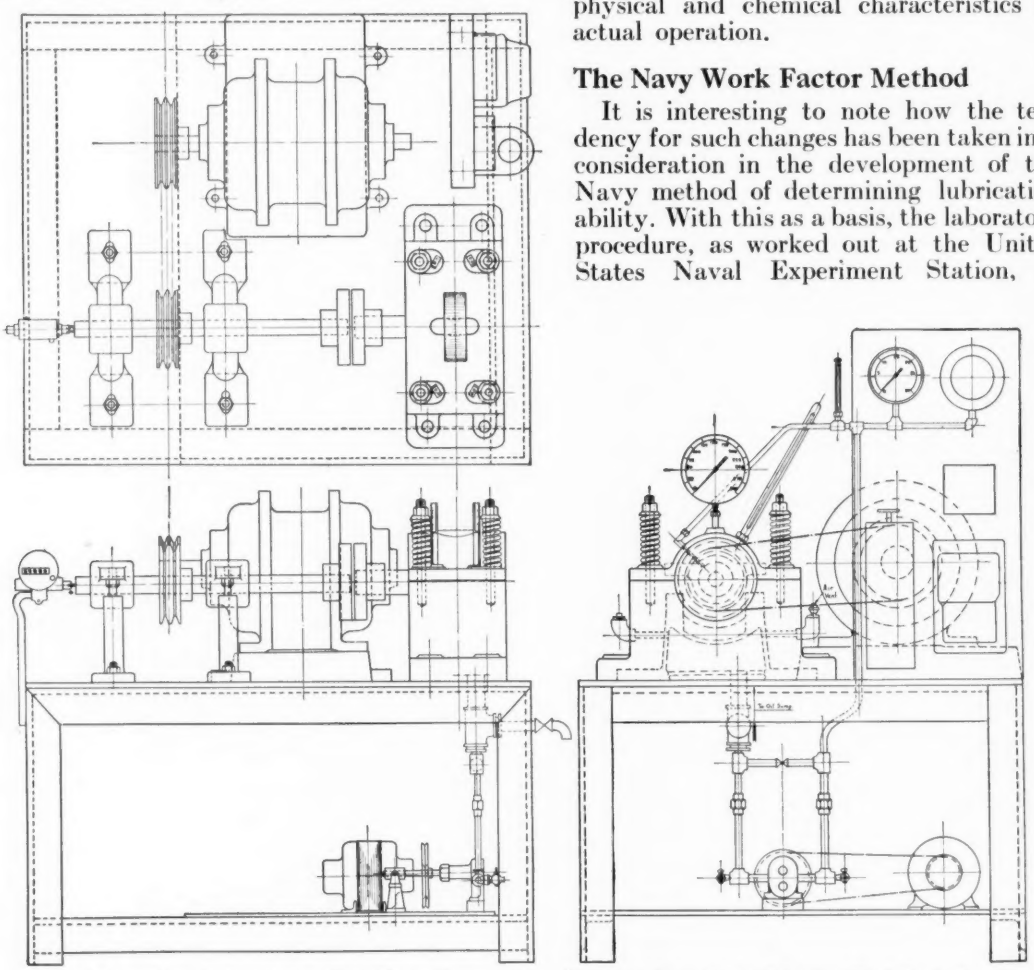


Fig. 1—This machine, developed by the United States Navy, consists primarily of a journal in a split bearing, $3^{55}/_{64}$ inches in diameter and $6^{1}/_{8}$ inches long, on which load is placed by four coil springs. It is driven by an electric motor at 2,000 r.p.m. The normal load on the bearing is 150 pounds per square inch. Under these conditions the apparatus is run for 100 hours, after which tests are made on the oil to show the changes resulting from the high temperature occurring in the oil film.

The Navy Work Factor Method

It is interesting to note how the tendency for such changes has been taken into consideration in the development of the Navy method of determining lubricating ability. With this as a basis, the laboratory procedure, as worked out at the United States Naval Experiment Station, at Annapolis, is of particular interest.

For years it has been realized that physical changes, notably with respect to viscosity, the percent of carbon residue, acidity and sludge formation have been indicative of what might be termed decrease in lubricating value. Until lately they have been considered individually, even though it was fully appreciated that they did not afford a practical means of indicating actual lubricating value, or variations in this latter.

Development of the Navy work factor machine has led to study of their composite relations. As a result, we have a practicable means of subjecting lubricating oils to an accelerated service or endurance test, wherein operating conditions can be maintained and controlled, dependent upon the service for which any particular oil is intended. According to James G. O'Neill,* this affords " . . . a convenient means for study of various problems of lubrication, such as: The effect on the oil of different bearing metals, the depreciation of the oil with excessive or scant flow of oil to the bearings, the effect of excessive vibration of the journals and, possibly, the effect of different gases on lubricating oil during operation. It is believed that the solution of these problems will be greatly aided by means of the endurance test and the work factor."

Grease Studies Involve Breakdown

Lubricating value of greases has been studied primarily with a view to determining the durability or resistance to breakdown. To accomplish this it has been necessary to design laboratory experimental apparatus which will carry a typical bearing installation and which can be so subjected to variation in speed, temperature and load as to render practicable the simulation of virtually any phase of actual operation. Certain manufacturers of anti-friction bearings have devoted much study to this phase of the problem.

In such a study of greases, it is perfectly feasible to run a sample under any set of predetermined operating conditions, the bearing and its lubricant being preferably visible during the entire run. This is an especially valuable feature inasmuch as it permits of constant observation of the lubricant. As a general rule, appreciable separation of the average grease can be readily noted. Since this phenomenon is the first indication of breakdown in a grease and reduction in lubricating value, obviously any testing device should permit of its discovery as soon as possible.

As a general rule, subjection of a grease to such a test, under carefully controlled temperatures, loads and speeds will indicate the range of these latter over which the product may be expected to retain its homogeneity and lubricating value.

Actual study of change of physical characteristics of a grease can be made in connection with the use of such a testing machine, just as the change in oil characteristics is studied in connection with the Navy Work Factor method.

On the other hand, no method of evaluating the extent of such changes has as yet been devised for use with greases. It is reasonable to presume, however, that with perfection and more extensive adoption of endurance methods of testing for actual lubricating value of greases, factors will be developed whereby one grease can be readily contrasted with another by virtue of the rate of change in its physical and perhaps chemical characteristics.

Gear Lubrication Requirements

To determine more specifically the characteristics which gear lubricants should possess in order to meet the intensive tooth loads and high rubbing speeds involved in modern automotive gear installations, the Timken Roller Bearing Company in turn has recently conducted some very interesting tests on a distinctive type of test machine, as shown in Fig. 2. The General Motors Corporation and others have also carried on work in a more or less similar manner.

These tests were instigated by the lack of definite information regarding the ability of lubricants used in transmission and rear axles to prevent scoring or scuffing under the higher tooth loads and rubbing speeds now coming into use, abrasion being studied with reference to anti-friction bearings of the type normally used in such installations.

While these tests are as yet comparatively new in nature, they have led the observers to draw conclusions to the effect that this type of testing machine is capable of developing data which will be of considerable comparative value in contrasting the actual lubricating ability of straight mineral gear lubricants with those containing compounds, such as lead soap, free sulfur, or aluminum stearate. Results seem to indicate, however, that a compromise between tooth scuffing and bearing wear must be allowed for, especially in the design of gears, with more consideration of the lubricating qualities of the average lubricants.

Calculation of the Navy Work Factor

The work factor itself is based upon the increase in viscosity, neutralization number, precipitation number and percent of carbon residue of a lubricating oil when subjected to service in the above mentioned machine. These numerical differences are incorporated into formulas to arrive at so-called work values for the respective tests. The average of these work values is termed the work factor of the oil under test. The respective formulas are noted below:

(1) Viscosity work value = 1.00 $\frac{\text{final viscosity} - \text{initial viscosity}}{\text{initial viscosity}} \times 5$
(For oils below 75 seconds Saybolt at 210°F.)

Viscosity work value = 1.00 $\frac{\text{final viscosity} - \text{initial viscosity}}{\text{initial viscosity}} \times 4$
(For oils above this viscosity)

*Chemist, U. S. Naval Engineering Experiment Station, Annapolis, Md. Paper on "The Work Factor of Lubricating Oil" Presented at Annual Meeting Am. Soc. Mech. Eng. Dec. 1930.

The neutralization number and precipitation number work values are each determined by the following formula:

$$(2)\ \text{Work value} = \frac{\text{final rejection point} - \text{final content or content of used oil}}{\text{final rejection point} - \text{initial content or content of new oil}}$$

The work value for carbon residue is figured both on the new and used oil. The average according to the following formula is taken as the carbon residue work value.

$$(3)\ \text{Work value for new oil} = \frac{\text{initial rejection point} - \text{initial content}}{\text{initial rejection point}}$$

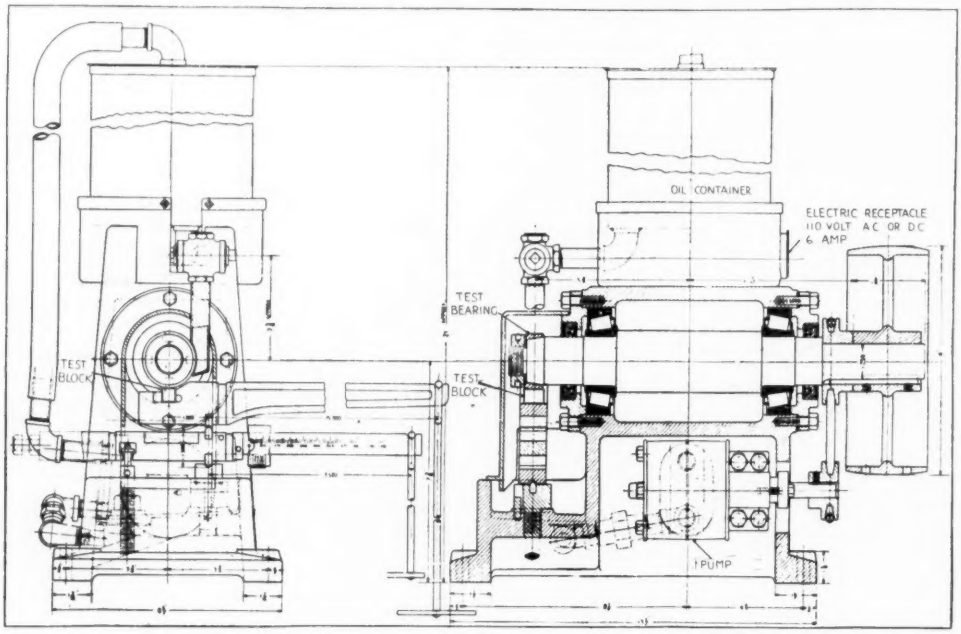
$$\text{Work value for used oil} = \frac{\text{final rejection point} - \text{final content}}{\text{final rejection point} - \text{initial content}}$$

any of the rejection points adopted in this connection.*

Much has been written of late†, both in explanation and discussion of this novel method of evaluating or expressing lubricating ability. In consequence, discussion of the machine will be limited to the accompanying illustration and its descriptive caption.

SIGNIFICANCE OF TESTS

It is felt, however, that more should be said concerning the meaning and interpretation of the physical and chemical tests to which the



Courtesy of The Timken Roller Bearing Company

Fig. 2—Sectional view of the Timken Lubricant Tester, showing general construction and over-all dimensions.

The average work factor is obtained by assembling the above data as follows:

Work value, viscosity at 100°F. .....
Work value, viscosity at 130°F. .....
Work value, viscosity at 210°F .....

$$(A)\ \text{Viscosity work value} = \frac{\text{total of above work values}}{3}$$

(B) Neutralization number, work value .....
(C) Precipitation number, work value .....
Work value, carbon residue, new oil .....
Work value, carbon residue, used oil .....

$$(D)\ \text{Carbon residue, work value} = \frac{\text{new and used oil, work values}}{2}$$

Total (A), (B), (C), and (D) .....

$$\text{Average work factor of oil} = \frac{\text{total of work values}}{4}$$

The highest work factor possible for an oil is 1.00. Where any of the above work values is less than zero, a zero rating is given. An oil having an average work factor less than 0.50 is not considered suitable for use, nor is any oil which, when subjected to the test, exceeds

oils are subjected prior to and following a period of test service in the above mentioned machine.

The Viscosity

According to the American Society for Testing Materials,§—"The significance of viscosity depends upon the purpose for which the oil is to be used.

"For lubricating oils viscosity is the most important single property. In a bearing operating properly, with a fluid film separating the surfaces, the viscosity of the oil at the operating temperature is the property which determines the bearing friction, heat generation, and the rate of flow under given conditions of

*Bureau of Engineering, Navy Dept. Pamphlet N. Eng. 31, P. 13. General Information for Refiners of Petroleum, regarding Tests of Lubricating Oils.

†Nat. Petroleum News, June 11, 1930; Amer. Soc. Mech. Eng. Annual Meeting, 1930; Jnl. Am. Soc. Naval Eng., Nov. 1929.

§The Significance of Tests of Petroleum Products—Report of Committee D-2 of the A.S.T.M. July 1929—P. 11-12.

load, speed and bearing design. The oil should be viscous enough to maintain a fluid film between the bearing surfaces, in spite of the pressure tending to squeeze it out. While a reasonable factor of safety is essential, excessive viscosity means unnecessary friction and heat generation. Since the rate of change of viscosity with temperature varies with different oils, viscosity tests should in general be made at that standard temperature which approximates most closely the temperature of use."

Precipitation Tests

Reference was made, earlier in this article, to sludge formation. It is of interest to note that the precipitation test will be indicative of this tendency.

This test as tentatively adopted by the A.S.T.M., involves dilution of the oil to be tested with a specific grade of petroleum naphtha, the precipitate being subsequently separated by centrifuging. The volume of this latter in milliliters is termed the A.S.T.M. Precipitation Number of the oil.

In discussing the significance of any such test it is stated that—*"The chief value of precipitation tests is in classifying the several groups of residual lubricating oils. Filtered products, such as the so-called 'bright stocks' largely used as constituents of motor oils, contain negligible quantities of asphalt. Another group which includes steam-refined cylinder stocks, is characterized by a moderate percentage of material that is insoluble in 'light' naphtha. So-called black oils, which are used for such purposes as the lubrication of gears . . . usually show precipitation tests that are moderately high."

Acidity as Determined by Neutralization

In view of the potential acid characteristics of virtually any petroleum lubricant, the acidity has come to be regarded as an important factor, especially in a study of steam turbine or internal combustion engine lubrication. In this case, it must be borne in mind that acidity which develops in use is undoubtedly detrimental, for it is almost invariably the prelude to sludging.

In discussing this, under the subject Neutralization, the A.S.T.M. advances some highly pertinent thoughts, viz.: †"Practically all petroleum lubricating oils contain substances, of varied and indeterminate chemical composition, which have acid characteristics. The proportion of these substances present in an oil is commonly referred to as its 'organic acidity.' These acid compounds are, mainly, natural constituents of crude petroleum and their presence in finished lubricating oil is not necessarily an indication of improper refining or poor quality.

"A large proportion of the petroleum lubricating oils now produced undergo treatment with mineral acid and caustic alkali in the course of refining. If the refining operations are not properly conducted, small quantities of one or the other of these chemicals may remain in the finished oil and, of course, are undesirable and unnecessary impurities.

"The 'Neutralization Number' of an oil is defined as the weight in milligrams of potassium hydroxide required to neutralize one gram of oil. It represents the sum of the quantities of mineral and so-called organic acids present in the oil or the difference between the organic acidity and the alkali present in the oil. If, as is usually the case, no mineral acid or alkali is present in the oil, the neutralization number is directly proportional to 'organic acidity'."

Significance of Results:

"It is obvious that the effect of alkali or mineral acid in a petroleum oil is deleterious, and it is usual to specify that the Alkali or Mineral Acid Neutralization Number shall be either zero or some extremely low figure. The practical significance of 'organic acidity' is complicated by many considerations. The essential facts are as follows:

1. Oils derived from certain crude oils commonly show low neutralization numbers while oils from other crude oils show relatively high neutralization numbers, unless subjected to special processes.
2. The organic acids normally present in lubricating oil are not corrosive and have no directly harmful effects.
3. It is contended by some, although the supporting evidence is not absolutely definite, that the presence of organic acids improves the friction-reducing qualities of oil.

"With these facts in mind, it is evident that the general quality of a lubricating oil cannot be evaluated in terms of its neutralization number. Specifications should never include limits on this property, unless it is known that an oil of low organic acidity is required."

Carbon Residue

This final test, which forms a part of the Navy Work Factor determination, is of interest due to the degree to which it may be indicative of subsequent difficulties on account of carbon residue accumulations. J. G. O'Neill, in his discussion of the adaptation of the work factor

*The Significance of Tests of Petroleum Products—Report of Committee D-2 of the A.S.T.M. July 1929—P. 37

†The Significance of Tests of Petroleum Products—Report of Committee D-2 of the A.S.T.M. July 1929—P. 42-43.

to aviation engine lubrication, advances some interesting thoughts in this regard. He states that—"The work factor method of qualifying aviation lubricating oils has so accurately demonstrated its value by a great number of practical tests that it is scarcely necessary to subject them to service tests in order to prove their suitability. Anyone familiar with the operation of high compression aviation engines recognizes the necessity of maintaining the pistons and cylinders free of carbon deposits; a very slight amount of carbon deposits on these parts greatly increases the detonating properties of the gasoline. While all are aware of the necessity of using gasoline which will withstand the high compression without detonation, very few take into consideration the fact that the use of a lubricating oil which produces carbon deposits on pistons or cylinders is just as objectionable as the use of an unsuitable gasoline."

In amplification of the above, the observations of the A.S.T.M.* are also of interest. They state that—"Petroleum products are mixtures of many compounds which differ widely in their physical and chemical properties. Some oils may be vaporized at atmospheric pressure and in the absence of air without leaving an appreciable residue, while other oils, upon distillation, leave a non-volatile carbonaceous residue. This residue when determined in accordance with prescribed procedure is designated 'carbon residue'. . . . .

"The carbon residue test was origin..lly developed for comparison of the carbon-forming properties of lubricating oils for internal combustion engines. It is frequently claimed that the quantity of carbon deposited in cylinders and on pistons is proportional to the carbon residue of the oil. Under ideal conditions this is probably true, but with average operating conditions, other factors such as the viscosity of the oil, the mechanical condition of the engine and the conditions of carburation of the fuel, may dominate in controlling carbon deposition."

*The Significance of Tests of Petroleum Products—Report of Committee D-2 of the A.S.T.M. July 1929—P. 40 and 41

CONCLUSION

It is apparent, from the above, that the change which may occur in a lubricant during actual operation must certainly be given due consideration, in original selection. There is far too great a tendency to choose such products based on their original specifications. Oftentimes, in fact, these are mentioned in contracts, without proper understanding of their relation to operating conditions.

It is impossible, of course, to simulate operating conditions absolutely in any laboratory determination of lubricating value. As a rule, these will vary over too wide a range. It is perfectly practicable, however, to carry on such work under standardized conditions of load, speed and temperature, varying any of these factors to conform to what might be considered abnormal operation.

The ultimate result, based on the methods as outlined heretofore would, without a doubt, give a better understanding of the extent to which the characteristics of a lubricant might change, and the degree to which such possible changes might be anticipated in preparing original specifications when in the market for such products.

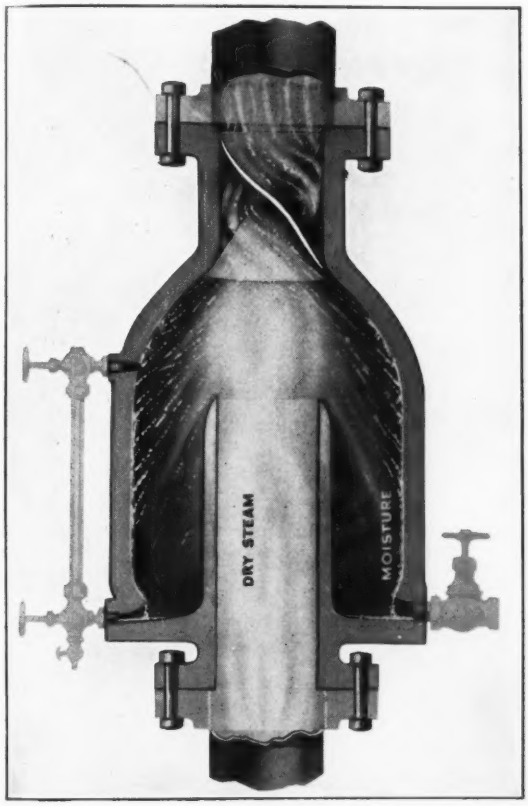
The Effect of Lubrication on the Use of Exhaust Steam for Process Heating

IN many phases of industrial plant operation steam, after it has performed its normal service in the development of power, or the operation of pumps and compressors, is used in process or auxiliary heating work. Familiar instances of this occur in textile industry dyeing operations, in paper machine calender rolls, in steam laundries, and in steam power plant feed water heating, wherein the heat still contained in the exhaust is efficiently utilized.

It is important to remember, wherever exhaust steam is to be used, either directly or indirectly for heating, that it will virtually always contain a certain amount of cylinder oil. The extent to which this may be a detriment, however, will depend upon the manner in which the heat from the steam is to be utilized. In normal practice such transfer of heat may be regarded as direct or indirect, according to whether steam is led directly into the solutions to be heated, as would prevail in open type feed water heaters, or whether it is passed through heating coils or drums.

Where steam is passed directly to dye vats, tanks, or open type feed water heaters, it may carry a certain amount of oil into the liquid to be heated; the oil, in turn, may be passed on to the goods under treatment, or back to the

boilers. In either case, this may be a decided detriment. In textile work staining may occur; in boiler room practice deposits or oily accumulations on the water side of the tubes may tend to reduce the rate of heat transfer.



Courtesy of The Swartwout Company

Fig. 1—Sectional view of a Swartwout Helico-Centrifugal Vertical separator. With this device the entering steam is subjected to a whirling motion and any entrained oil is thereby thrown by centrifugal force to the outside of the separator, where it runs down and is drawn off.

Where steam is used in an indirect manner for heating processes, however, one need only be concerned with accumulations of oil deposits within the heating surfaces, which would, of course, have the same effect as on boiler tubes, i.e., reduction in the rate of heat transfer.

It is obvious, therefore, that where exhaust steam is to be used in this manner more attention should be given to steam cylinder lubrication. It may be stated that very frequently the steam cylinders of engines, pumps or compressors are over-lubricated. In general, however, this will not be apparent until the machinery is taken down for over-haul. Normally such a condition may prevail for a considerable length of time before over-haul will be essential and yet all this time an excess of oil will be carried over by the exhaust steam, as a potential cause of trouble.

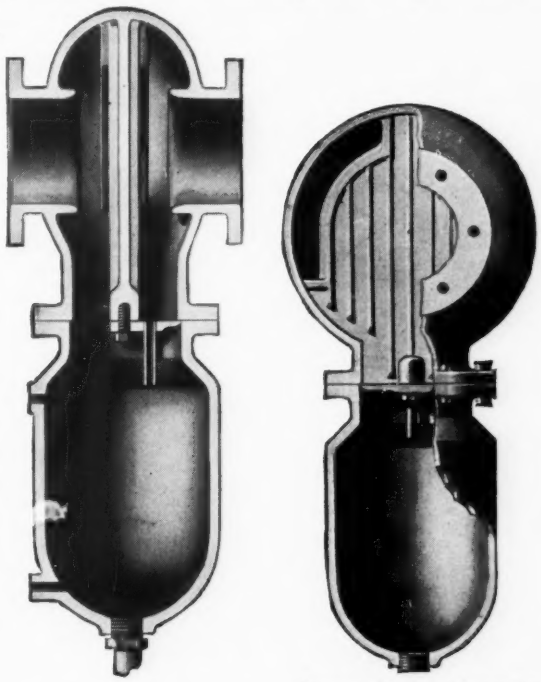
TEXTILE DYEHOUSE OPERATIONS

In the dyeing of textile yarns or fabrics the utmost care must be taken to preserve the purity of the dyeing solutions as well as the water used for washing. This will be especially applicable to skein dyeing operations where the yarn is dyed prior to weaving. In such practice, the woven goods are often not subjected to any further washing, final treatment being confined to shrinking, ironing, etc., according to the nature of the product.

The presence of lubricating oil, must be prevented, therefore, wherever possible, for it has been found that it impairs the process of dyeing, causing uneven spreading of certain dyes, and frequently streaks in the finished goods.

As a result, in view of the practice of using exhaust steam for direct heating of dye liquors and wash waters in certain dyehouses, the detriments which may accrue from the use of an excess of cylinder oil in pumps or engines must be realized.

Where exhaust steam is to be used in this manner, oil separators can be installed. In general they can be depended upon to be reliable in removing any cylinder oil which might be detrimental to products such as silk or rayon.



Courtesy of Cochrane Corporation

Fig. 2—Showing the general construction of the horizontal type of Cochrane separator. In this device the condensate is deflected into a well by the main baffle, which is located directly across the steam current so that the suspended particles strike against it. This baffle is provided with vertical ribs to prevent steam from scrubbing oil off. The oil flows directly down between the ribs, into the oil well.

Where a separator is not used, however, it is often customary to sacrifice lubricating ability

to some extent, although indirect heating would be the most positive method of preventing the possibility of oil streaks or stains. On the other hand, indirect heating would involve a more expensive layout of pipe coils in the various tanks.

Courtesy of The Hoppes Manufacturing Co.

Fig. 3—Ascending current type of oil eliminator. Considerable attention has been given to design, so as to obstruct steam flow as little as possible.

EFFECT ON BOILER OPERATIONS

Oil in the form of fine emulsions in a boiler combines with the boiler compounds to cause foaming, or reaction with the boiler water impurities to produce a coating over the tubes and fire surfaces. This coating seems to form more readily over relatively clean tubes than over dirty ones.

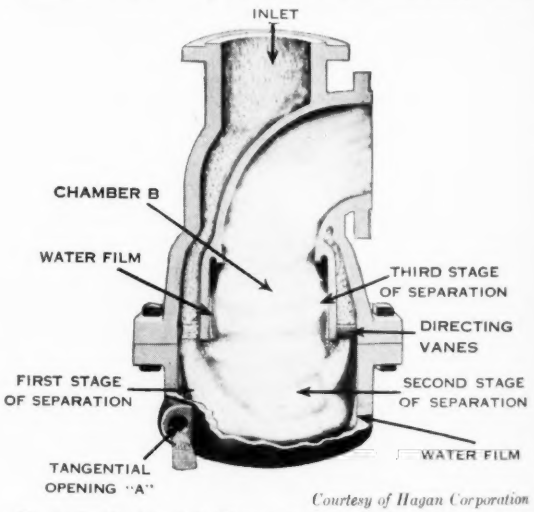
A very thin layer of oily sludge over a tube surface will so insulate it that there is not only a large loss in heat efficiency, but also the rise in temperature of the metal may be so excessive as to cause burning out or explosion of the boiler tubes.

The remarks of the Elliott Company are particularly interesting in this regard, viz.:

"Oil can perhaps do more damage in proportion to its bulk than any other substance that is likely to be carried into the boiler with the feed water. In the boiler, oil or grease tends to form a film or coating over the entire inner surface, and this film is a highly efficient heat insulator, separating the water from the heating surfaces, causing dangerous overheating of tubes and sheets and lowering the rate of heat transmission through the tubes. If only the slightest amount of oil and grease is present in the feed water when it is injected into the boiler, a distinct falling off in efficiency can be noted. Oil and grease also combine with scale-forming material to form a scale which is very hard to remove and, of course, doubly detrimental to both operating efficiency and

Courtesy of Wright-Austin Company

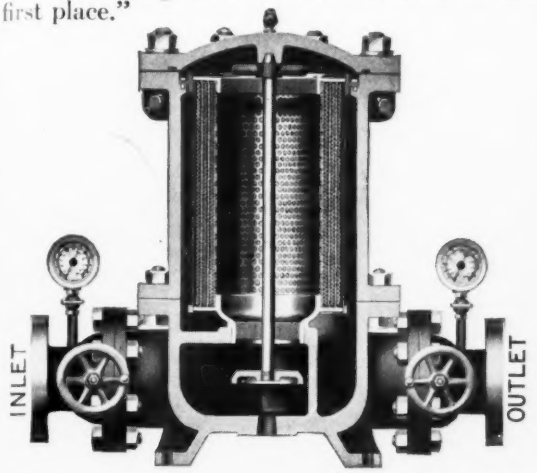
Fig. 4—Horizontal type of Wright-Austin, self-cleaning oil separator. Note that this device is one solid casting, the baffle being attached to the body of the separator by lugs.



Courtesy of Hagan Corporation

Fig. 5—Inside view of the Hagan separator, showing the three stages of centrifugal separation. The steam first passes through a set of directing vanes, being given a high rotating or whirling velocity by centrifugal force, aided by gravity. The oil content is thrown against the cylindrical wall of the separator bowl, being discharged through a tangential opening. Direction of flow of steam is then reversed, and subjected to the same rotary velocity in its ascension. The third stage of separation occurs in Chamber B.

safety. Oil in the boiler is sure to cause repair bills amounting to a great deal more than the cost of keeping the oil out of the boiler in the first place."



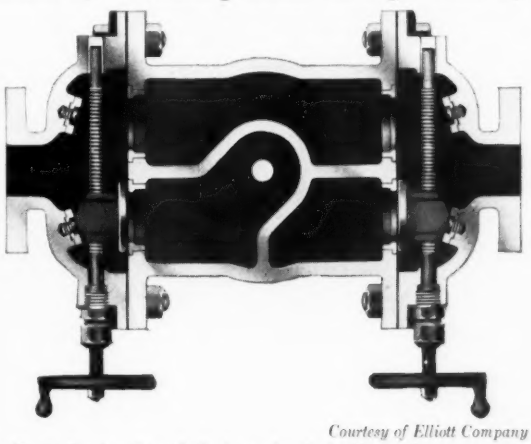
Courtesy of Elliott Company

Fig. 6—Showing details of the Lagonda "Multiple Filtration" filter and grease extractor. Note the perforated spool and layers of filter cloth. Direction of flow is from the inside of the filtering medium to the outside, so that all organic matter, oil sediment, etc., contained in the condensate is accumulated on the inside of the spool, and removed with the filtering element when it is taken out for cleaning.

PAPER MILL CALENDER OPERATIONS

In the paper industry indirect heating by means of exhaust steam is brought about in the operation of certain types of calender stacks. The purpose of the calender is to give the paper a high grade finish as it leaves the dry end of the paper machine. This is accomplished by passage through a stack of calender rolls.

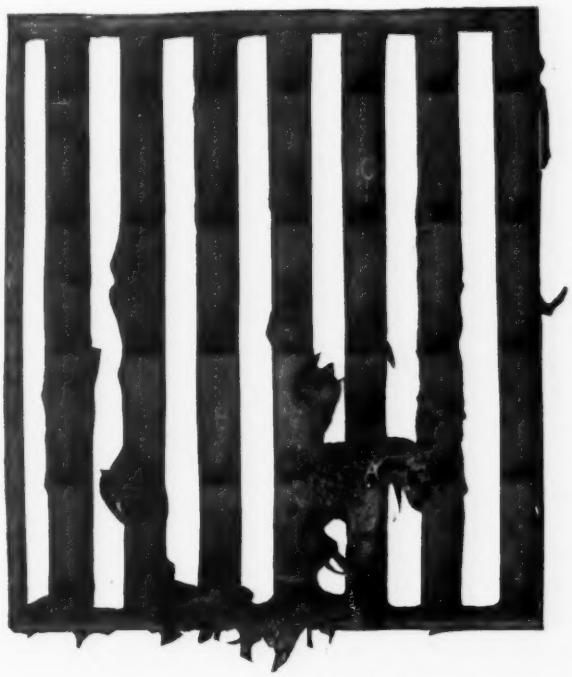
Heating of certain of these rolls is brought about by circulating steam through them by



Courtesy of Elliott Company

Fig. 7—Section through the base of a single filter and grease extractor, showing in particular the valve arrangement for control of flow of condensate.

means of suitable steam joints. Wherever exhaust steam is to be used for this purpose it has been found advisable to employ some means to remove any cylinder oil which may have been carried over from the engines. Otherwise the interior of the rolls will become so coated with oil and grease accumulations as to markedly reduce the rate of heat transfer. In extreme cases this would require slowing



Courtesy of Cochrane Corporation

Fig. 8—Showing a grease covered grid from a multiple-baffle Cochrane separator, indicating the condition that will prevail if frequent cleaning is not observed.

down of the machine to bring about the proper degree of drying.

It is good practice in the paper industry, therefore, to employ oil separators in the exhaust steam lines adjacent to such rolls.

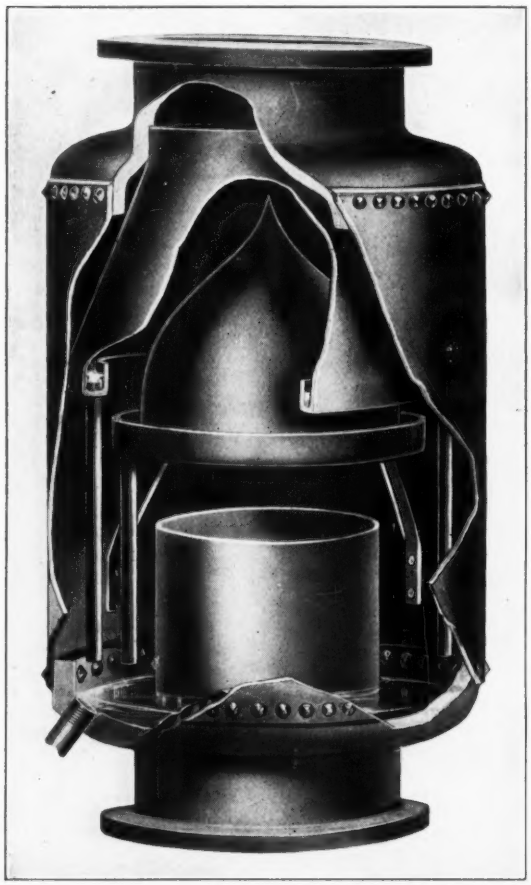
SELECTION OF STEAM CYLINDER OILS

In view of the foregoing, it is obviously important to study those factors in steam cylinder lubrication which may foster retention of oil by the exhaust.

As a general rule, it is felt that these will involve the rate of oil feed, the type of engine, and the amount of compound used. The former can, of course, be controlled by the operator; in an existing plant, however, the type of engine, pump or compressor is fixed. Compounding in turn is a refinery process; plant operators, on the other hand, by judicious study of cylinder oil characteristics, can obtain such products with varied amounts of a number of fixed oil compounds, according to their plant and engine requirements. The use to which the exhaust steam is to be put is of decided importance in connection with these latter.

Moisture a Factor in Compounding

The purpose of compounding is to improve the adhesiveness of steam cylinder lubricants. It is, therefore, a function of the moisture content of the steam. From the viewpoint of actual



Courtesy of The Hoppes Manufacturing Co.

Fig. 9—Showing interior construction of a descending current type of oil eliminator. Note in particular the construction of the troughs which intercept entrained oil. A pipe from every trough carries oil and surplus water to the bottom of the eliminator, from which it can be piped to a receiver or trap.

composition of a cylinder oil, the question of moisture in the steam is the most important factor involved.

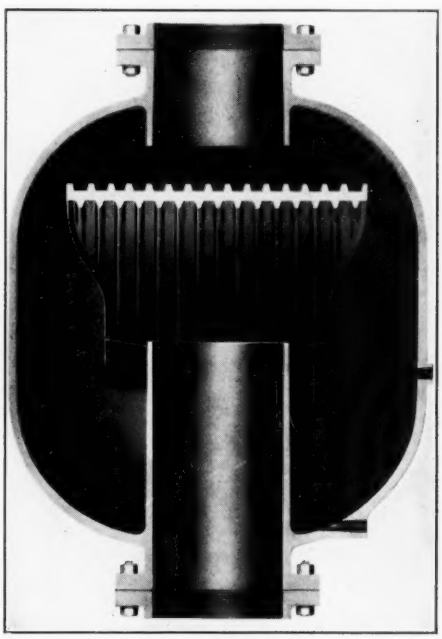
Steam will always contain a certain percentage of moisture unless it is superheated to a sufficient extent to counteract any line and cylinder condensation which may be caused by the cooling effect of the piping or cylinder walls, and the expenditure of heat by the expansion stroke. The presence of moisture in steam will usually result in a film of straight mineral lubricating oil being rapidly washed off from the cylinder walls and other surfaces with which the steam comes in contact. Therefore, to secure proper lubrication under wet steam conditions it is necessary to increase the rate of flow of the straight mineral oil, or substitute an oil which contains a certain percentage of fatty compound such as lard oil, degras or tallow.

The use of a straight mineral oil to lubricate wet steam is customary only where the presence of a fatty oil in the exhaust steam is objectionable. The increased amount necessary to insure proper lubrication will often result in imperfect atomization. As a consequence, oil accumulations in the cylinder will be prevalent and carbon deposits developed.

Especially will the above be true in multiple expansion engines equipped with re-heaters, the high temperatures to which the oil is subject being very conducive to carbonization. In poppet valve engines carbon formation of this nature may often cause imperfect operation of the valves.

Compounding Aids in Emulsification

Where a compounded oil is used an emulsion is developed by the moisture in the steam reacting with the fatty component. The lubricating film thus has a greater affinity for the cylinder walls and other wearing surfaces and becomes highly resistant to the washing action of the water in the steam. Naturally the greater the percentage of moisture in the steam the higher



Courtesy of Wright-Austin Company

Fig. 10—Showing the Wright-Austin vertical type of self-cleaning oil separator. Note the large clearance areas and the arrangement of baffles.

should be the fatty compound content of the lubricant. In general the compound should not exceed 10 per cent however, except in extreme cases of abnormally wet steam. It should be remembered that an excessive

amount of fatty compound, beyond that necessary to form the requisite emulsion, will not improve the lubricating value of the oil. In fact, it may even be an objection, especially under continued exposure to high temperatures, on account of the tendency that animal fats have to decompose under such conditions.

Amount of Compounding

In regard to the proper amount of compound to use in an oil, it can be said that this should be just sufficient to maintain a film of oil on the cylinder walls. This is especially true where the exhaust steam is to be used for feed water heating or in process work of any nature. Under such conditions it is more important than ever to observe caution in selecting and using steam cylinder lubricants.

Present day practice is more and more to reduce the quantity of compound and to improve its quality.

That tendency in compounded oils which causes them to unite with water to form emulsions in the cylinders also prevents ready separation from water in condensed steam; furthermore, the more completely atomized

Courtesy of Elliott Company

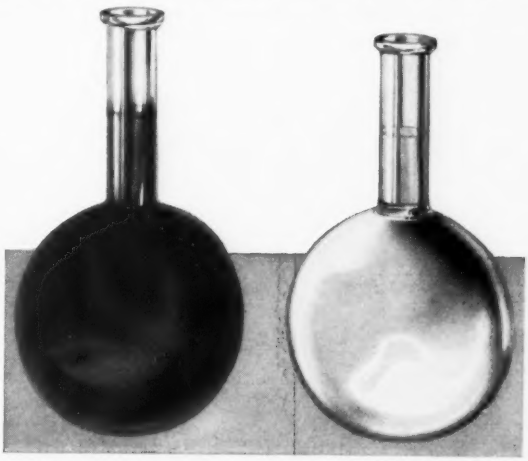
Fig. 11—Showing interior of an Elliott Type "P" separator, bringing out details of baffle arrangement. In this device changing the direction of steam flow effectively separates the oil from the condensate, the former draining to the bottom of the separator.

the oil, the more difficulty will it have in separating from water.

In this respect, it also is of interest to note that compounding improves the atomizing ability of the average cylinder stock. For this reason it must be confined within the lowest possible limits where exhaust steam is to be used for open feed water or process heating purposes.

Engine Construction

The type of engine must be given due consideration in the selection of any steam cylin-



Courtesy of Hagan Corporation

Fig. 12—Showing samples of condensate from the exhaust from a 500 h.p. Una-flow engine. At the left is shown oil and moisture as removed from the separator. At the right is shown the clean condensed exhaust leaving the separator.

der oil. In the horizontal cylinder, except where tail rods are used, the weight of the piston, rings and part of the weight of the piston rod may be borne by the lower portion of the cylinder, especially if these parts are not in proper alignment. On account of this weight the piston will frequently tend to wear the bottom of the cylinder out of round, and unless sufficient lubrication is provided, the clearance between the piston and the cylinder may become great enough to cause serious leakage of the steam past the piston. This increases the pressure to which the oil film is subjected and may weaken or entirely destroy it.

If the rings become worn and sharp on the edges they will scrape the oil film off the surface of the cylinder walls, to increase the friction and wear. Because of these conditions the cylinder oil must have the characteristics which will provide a heavy lubricating film and must be used in sufficient quantities to maintain it. Even with the most efficient oil a certain amount of wear will take place and the rings will have to be renewed occasionally.

Tail Rod Supports an Advantage

Engines having heavy pistons and rods are, therefore, usually provided with tail rod supports, which, together with the cross head, carry the weight of the former. In such engines the only pressure on the cylinder walls is that carried by the tension of the piston rings, and

a thinner film of oil and a lesser quantity of lubricant are required.

Vertical Engines

Vertical cylinders, on the other hand, are comparatively simple to lubricate as the weight of the piston, piston rod, cross head and connecting rod are carried by the crank pin. The only pressures on the cylinder walls are those due to the tension of the piston rings and possibly to some slight pressure from any lateral motion which the piston may have.

The rings, no matter of what design, should be accurately set, and just tight enough to prevent any abnormal steam leakage. A film of oil thick enough to prevent excessive friction between these rings and the cylinder walls, and enough oil to maintain this film, are all that is required to provide proper lubrication.

In this connection it is noteworthy to mention that those lower to medium horse power units of the vertical type which are eminently satisfactory for average plant service, could be expected to be a decided adjunct where the minimum of cylinder lubrication is essential in the interests of oil-free exhaust steam. This would apply to stoker drives, vertical steam pumps, and engines used for driving generators and air compressors.

FUNCTION OF THE OIL SEPARATOR

While the oil content of exhaust steam can in part be controlled by judicious selection and application of steam cylinder oils, with prime moving machinery wherever the presence of oil in the exhaust may be a detriment to subsequent usage of this latter it will be advisable, as heretofore mentioned, to consider installation of an oil separator or eliminator, or a grease extractor.

According to the Cochrane Corporation, the oil separator serves a two-fold purpose:

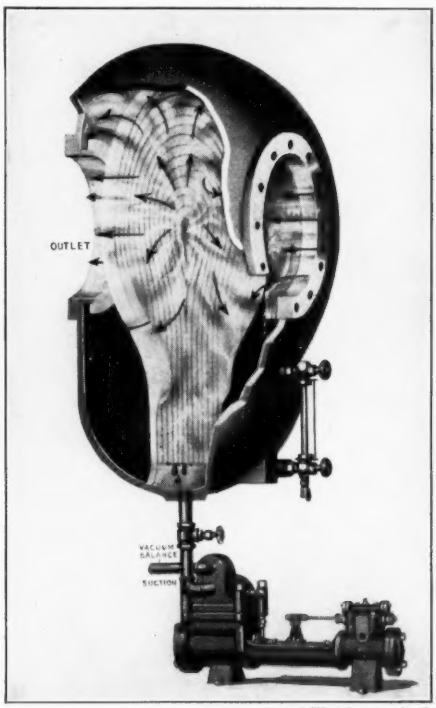
"First, to render the water which is condensed from the steam or water which may be heated by direct actual contact with the steam, as in open feed water heaters and jet condensers, suitable for boiler feeding and industrial purposes, and

"Second, to prevent a coating of oil or grease from forming upon surfaces with which the exhaust steam may come in contact, as the interior surfaces of radiators, heating and calendering rolls, cooking kettles, surface condensers, closed heaters, etc.

"Paper mills find it highly beneficial to install oil separators in the exhaust steam lines close to the calendering rolls, as they have a decided effect in maintaining the capacity of the machines. Without the separator the interior of the rolls becomes coated with grease, which diminishes the transmission of heat and necessitates slowing down of the machine in order to secure proper drying of the product. The use of the separator also makes it unnecessary to increase the back pressure in order to secure higher temperature for the purpose of promoting the flow of heat. The avoidance of high back pressures naturally improves the economy of the engine."

In the design of an oil separator cognizance must be taken of the manner in which cylinder oil will be contained in the exhaust steam. It is the general theory that it will appear both in the form of an emulsion, by reason of the compound content of the original oil, and as a suspended mist. This latter can be attributed to the straight mineral proportion. As a general rule, there will be but little free oil actually in evidence unless over-lubrication has been carried out to excess. Normally the appearance of the steam will be milky or slightly opalescent. In the form of condensate it can be likened to water which contains an excess of air.

With all this intimate mixture, however, it is not a difficult matter to remove practically the entire oil content from exhaust steam. Analyses have shown that this can be accomplished to the extent that the resultant steam will carry only one half part of oil per million parts of water. Exhaust steam purified to this extent is regarded as entirely dependable for virtually any type of direct or indirect process heating work.



Courtesy of Wright-Austin Company

Fig. 13—Cutaway view of a Wright-Austin separator, showing special vacuum pump attachment for drainage.

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